

A Uniform Correlation between Synchrotron Luminosity and Doppler Factor in Gamma-ray Bursts and Blazars: hint of similar intrinsic luminosities?

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ABSTRACT

We compile 23 Gamma-ray Bursts (GRBs) and 21 blazars with estimated Doppler factors, and the Doppler factors of GRBs are estimated from their Lorentz factors by assuming their jet viewing angles $\theta \rightarrow 0^\circ$. Using the conventional assumption that the prompt emission of GRBs is dominated by the synchrotron radiation, we calculate the synchrotron luminosity of GRBs from their total isotropic energy and burst duration. Intriguingly, we discover a uniform correlation between the synchrotron luminosity and Doppler factor, $L_{\text{syn}} \propto \mathcal{D}^{3.1}$, for GRBs and blazars, which suggests that they may share some similar jet physics. One possible reason is that GRBs and blazars have, more or less, similar intrinsic synchrotron luminosities and both of them are strongly enhanced by the beaming effect. After Doppler and redshift-correction, we find that the intrinsic peak energy of the GRBs ranges from 0.1 to 3 keV with a typical value of 1 keV. We further correct the beaming effect for the observed luminosity of GRBs and find that there exists a positive correlation between the intrinsic synchrotron luminosity and peak energy for GRBs, which is similar to that of blazars. Our results suggest that both the intrinsic positive correlation and the beaming effect may be responsible for the observed tight correlation between the isotropic energy and the peak energy in GRBs (so called “Amati” relation).

Subject headings: gamma-rays: bursts - BL Lacertae objects: general - galaxies: jets - methods: statistical

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1. Introduction

Blazars are a subclass of active galactic nuclei (AGNs), including flat-spectrum radio quasars (FSRQs) and BL Lac objects (BL Lacs), which are believed to be radio loud AGNs with their jets oriented at relatively small angles with respect to the line of sight. Special relativity plays a key role in spectral calculations of the relativistic plasma outflow. One of the most important effects is the relativistic boosting of the radiation, which is primarily governed by the value of the Doppler factor $\mathcal{D} = [\Gamma(1 - \beta \cos \theta)]^{-1}$ [$\Gamma = (1 - \beta^2)^{-1/2}$ is bulk Lorentz factor, β is jet speed divided by speed of light, and θ is the angle between the jet and the line of sight]. Several different approaches have been proposed to estimate the Doppler factor \mathcal{D} of the jets in AGNs. Ghisellini et al. (1993) estimated the Doppler factor with the very long baseline interferometry (VLBI) core sizes/fluxes, and the X-ray fluxes assuming the X-ray emission to be produced by the synchrotron self-Compton (SSC) processes in the jets. Lähteenmäki & Valtaoja (1999) proposed that variability brightness temperature of the radio source may be caused by the relativistic jets, and the Doppler factor can be estimated by assuming the intrinsic brightness temperature of the source is limited to the equipartition value. The apparent jet speed β_{app} can be measured from the multi-epoch VLBI observations, with which the Lorentz factor and the viewing angle of the jet can be derived, if the Doppler factor \mathcal{D} and β_{app} both correspond to the same underlying flow speed. Hovatta et al. (2009) calculated the Doppler factor, Lorentz factor and viewing angle for a sample of blazars from their variability brightness temperature and apparent jet speed, and found that the Lorentz factors of blazars range from 2 to 30 with a typical value $\Gamma \sim 15$.

Gamma-ray bursts (GRBs) are the most luminous astrophysical events so far. It is well known that GRBs produce ultrarelativistic and beamed jets with total isotropic-equivalent energy $E_{\text{iso}} \sim 10^{49-55}$ erg (e.g., Mészáros 2006; Zhang 2011, for reviews and the references therein). Unlike the large-scale jets observed in AGNs, the jets are not observed in GRBs directly. There are several methods to constrain the Lorentz factors of the prompt emission of the GRBs and the typical Lorentz factors are found to be around several hundreds, which are mainly based on the “compactness” argument (e.g., Fenimore et al. 1993; Zou et al. 2011), the flux and temperature of the thermal component of some GRB spectra (e.g., Pe’er et al. 2007), or the early afterglow light curves with the signal of fireball deceleration (e.g., Sari & Piran 1999; Liang et al. 2010; Ghirlanda et al. 2011).

The spectral energy distribution (SED) of blazars is characterized by two broad components: the low-energy component peaked at infrared-soft X-ray wavebands and the high-energy component peaked at MeV-GeV wavebands. There is unanimous consensus that the first broad peak is due to the synchrotron emission, while the nature of the second peak re-

mains controversial. Comptonization is believed to be responsible for the high-energy γ -ray emission, which can be classified into two categories: the synchrotron self-Comptonization (SSC) model and the external Comptonization (EC) model, according to the origin of the soft seed photons. The external soft seed photons may originate from the accretion disks, the broad line regions and/or the dust tori (e.g., Böttcher 2007, for a review and the references therein). The nature of the prompt emission of GRBs is still a mystery. The SED of the prompt emission of GRBs is normally peaked at around several hundred keV to MeV waveband, which can be well fitted with a smoothly-jointed broken power-law, the so-called Band function (e.g., Band et al. 1993). The most successful theory to explain the prompt emission of GRBs to date is nonthermal synchrotron emission caused by the internal shocks due to the collision of two relativistic shells (e.g., Mészáros et al. 1994; Tavani 1996), though it still suffers some criticisms (e.g., Zhang 2011, for a recent review and the references therein). The synchrotron spectra may extend to a few hundred keV in the observer frame if the Lorentz factors of the GRBs $\Gamma \sim 100\text{--}1000$, and the inverse Compton scattering of such photons leads to GeV and TeV spectral components (e.g., Mészáros et al. 1994).

It is found that both blazars and GRBs seem to form a sequence respectively, as functions of the power, with their overall SEDs. However, the trends of these two sequences are opposite to each other. Fossati et al. (1998) found that the peak frequency of synchrotron emission decreases with increasing luminosity for a sample containing ~ 100 blazars (see also Ghisellini et al. 1998). However, the peak energy of the νF_ν spectrum, E_{peak} , was found positively correlated to the total isotropic energy (E_{iso} , e.g., Amati et al. 2002; Ghirlanda et al. 2004) or the isotropic luminosity (L_{iso} , e.g., Liang et al. 2004; Yonetoku et al. 2004) in the GRBs. A quite strong $E_{\text{iso}} - E_{\text{peak}}$ correlation is also discovered for some individual GRBs, which has the similar slope and normalization as those defined by the different GRBs (e.g., Firmani et al. 2009; Ghirlanda et al. 2010; Lu et al. 2010). The physical origin for these correlations (in particular, the opposite trends) in blazars and GRBs is still unclear. One possibility is that they are caused by the Doppler beaming effect, since that both the radiation and the peak frequency/energy are affected by the Doppler factor. Nieppola et al. (2008) and Wu et al. (2008) found that the negative correlation between the synchrotron peak frequency and luminosity in blazars becomes positive after correcting the Doppler boosting effect for these two quantities. Liu et al. (2010) proposed that the temporal and spectral evolution in GRB pulse can be explained with the Doppler beaming effect caused by the jet precession.

In this *Letter*, there are two motivations for studying the beaming effect in GRBs and blazars: (1) understand the intrinsic values of the peak energy and luminosity in GRBs after eliminating the Doppler boosting effect; (2) explore the possible similarities of the jet physics in GRBs and blazars. Throughout this work, we assume the following cosmology:

$H_0 = 71 \text{ km s}^{-1}\text{Mpc}^{-1}$, $\Omega_0 = 0.3$ and $\Omega_\Lambda = 0.7$.

2. Sample

Our sample includes two parts: GRBs and blazars. The most important selection criterion is that their Doppler factors have been estimated in the literature or can be estimated in this work. We briefly describe the sample as follows (see also Table 1 for the details).

The GRB sample includes 23 sources with redshift measurements, and the initial Lorentz factors of the prompt emission have been constrained from the early afterglow of optical and/or X-ray light curve with a signal of fireball deceleration, which are selected from Liang et al. (2010). The Lorentz factor of GRB 080319C has been estimated from the optical light curve and X-ray light curve separately, and the Lorentz factors constrained with these two methods are included in our sample, as they are roughly consistent with each other. We note that the Lorentz factor estimated from the “compactness” argument or blackbody component is not included in this work, due to it still suffering great uncertainties (e.g., Fenimore et al. 1993; Pe’er et al. 2007). The Doppler factors of GRBs are simply estimated with $\mathcal{D} \sim (1 + \beta)\Gamma \sim 2\Gamma$ due to the Lorentz factors of GRBs $\Gamma \gg 1$ and the viewing angles $\theta \rightarrow 0^\circ$ (e.g., Mészáros 2006). To compare with the blazars, we evaluate the luminosity of GRBs from their total isotropic energy E_{iso} and time duration T_{R45} , where E_{iso} and T_{R45} are selected from Butler et al. (2007, 2010). The total isotropic energy E_{iso} is defined in the energy between $1 - 10^4 \text{ keV}$, and T_{R45} is the total time interval of the brightest bins in the light curve that contains 45% of the burst fluence (Reichart et al. 2001). The peak energy of GRBs is a key parameter, which may help us understand the jet radiation processes, and therefore, we also selected the data of the observed peak energy of GRBs from Butler et al. (2007, 2010).

The blazar sample in this work consists of 21 sources. The Doppler factors, \mathcal{D} , of these blazars are estimated from the variability brightness temperature by assuming the intrinsic brightness temperature of the equipartition value (see Savolainen et al. 2010, for more details and the references therein). The blazars with Doppler factors estimated from the X-ray fluxes and VLBI core sizes/fluxes, assuming the SSC origin of X-ray emission, are not included in this work, since the hard X-ray emission of many blazars may be dominated by the external Compton emission (e.g., Ghisellini et al. 2010). The second selection criterion of the blazars is the multi-frequency, simultaneous observational data of SEDs, which allows us to estimate their total synchrotron luminosities and the synchrotron peak energy. We select the blazars from Abdo et al. (2010), where all sources have quasi-simultaneous (within 3 months), broad-band observed SEDs. The peak frequency of synchrotron emission was estimated by fitting

the part of the SED dominated by the synchrotron emission with a third-degree polynomial equation (see Abdo et al. 2010, for the details), which is also listed in Table 1. With the two criteria described above, 21 blazars are selected from Savolainen et al. (2010) and Abdo et al. (2010).

3. Results

3.1. $L_{\text{syn}}\text{-}\mathcal{D}$ Correlation in GRBs and Blazars

The Doppler factors of GRBs are estimated from their Lorentz factors with $\mathcal{D} \sim 2\Gamma$. The distributions of the Doppler factors of blazars and GRBs are presented in Figure 1. The average value $\langle \log \mathcal{D} \rangle = 1.21$ with standard deviation $\sigma = 0.2$ for blazars, and $\langle \log \mathcal{D} \rangle = 2.74$ with $\sigma = 0.25$ for GRBs respectively.

Using the conventional assumption that the prompt emission of GRBs is dominated by the synchrotron emission, we calculate the isotropic synchrotron luminosity of each GRB from its total isotropic energy, E_{iso} , and burst duration, T_{R45} , with $L_{\text{syn}} = E_{\text{iso}} / [T_{\text{R45}}(1+z)]$. We present the relation between the synchrotron luminosity, L_{syn} , and the Doppler factor, \mathcal{D} , in Figure 2 (red circles). It is found that L_{syn} is positively correlated to \mathcal{D} for these GRBs. The best fitting (long-dashed line) gives

$$\log L_{\text{syn}} = (3.38 \pm 0.50) \log \mathcal{D} + (42.85 \pm 1.36), \quad (1)$$

with the Spearman’s rank correlation coefficient $r = 0.86$ (chance probability $p < 10^{-8}$).

To estimate the total synchrotron emission of blazars, we integrate the best-fitted spectrum of the synchrotron component of every blazar (see Abdo et al. 2010, for the details). The synchrotron luminosities of these blazars are listed in Table (1). The correlation between L_{syn} and \mathcal{D} for blazars is shown in Figure 2 (red squares). The best linear fitting (short-dashed line) gives

$$\log L_{\text{syn}} = (2.56 \pm 0.52) \log \mathcal{D} + (44.37 \pm 0.63), \quad (2)$$

with the correlation coefficient $r = 0.67$ (chance probability $p = 3.2 \times 10^{-4}$).

Our results indicate that the synchrotron luminosity L_{syn} is closely correlated with \mathcal{D} both for GRBs and blazars. Furthermore, it is found that GRBs and blazars roughly follow the same correlation between L_{syn} and \mathcal{D} (see Figure 2). For the entire sample of GRBs and blazars, the best fitting (red solid line) gives

$$\log L_{\text{syn}} = (3.10 \pm 0.11) \log \mathcal{D} + (43.71 \pm 0.21). \quad (3)$$

The Spearman test gives the correlation coefficient $r = 0.98$ and chance probability $p < 10^{-8}$. The tight correlation between L_{syn} and \mathcal{D} in both GRBs and blazars may provide a hint for their jet similarities, which will be discussed below.

3.2. The Intrinsic $E'_{\text{peak}}-L'_{\text{syn}}$ Correlation in GRBs and Blazars

The redshift and Doppler-correction of peak energy of GRBs and blazars can be calculated by using

$$E'_{\text{peak}} = E_{\text{peak}} \left[\frac{1+z}{\mathcal{D}} \right], \quad (4)$$

where the primed symbol represents the value measured in the source rest frame. We find that the values E'_{peak} range from ~ 0.1 to ~ 3 keV for GRBs, and $\sim 10^{-6} - 10^{-3}$ keV for blazars, respectively. The distribution of $\log E'_{\text{peak}}$ is plotted in Figure 3, where $\langle \log E'_{\text{peak}} \rangle = -0.15$ with standard deviation $\sigma = 0.38$ for GRBs and $\langle \log E'_{\text{peak}} \rangle = -5.02$ with $\sigma = 0.48$ for blazars.

The observed synchrotron emission being amplified due to the Doppler boosting effect can be described by $L_{\text{syn}} = \mathcal{D}^{\alpha} L'_{\text{syn}}$, where L'_{syn} is the intrinsic synchrotron luminosity in the source rest frame. The beaming factor index α depends on the detailed physics of jets (i.e., $\alpha = 3$ for a continuous jet and $\alpha = 4$ for a moving sphere, see Ghisellini et al. 1993, for more details). Here, we simply assume $\alpha = 3.5$ (a middle value between 3 and 4) to estimate their intrinsic synchrotron luminosities. The relation of the intrinsic synchrotron luminosity L'_{syn} and the peak energy E'_{peak} measured in the rest frame of the source is presented in Figure 4 for GRBs (squares) and blazars (circles). The Spearman's rank correlation coefficient $r = 0.38$ (chance probability $p = 0.05$) for the GRB sample, and $r = 0.55$ (chance probability $p = 0.005$) for the blazar sample, are derived. The Spearman test results suggest a positive correlation between the intrinsic quantities of L'_{syn} and E'_{peak} for GRBs and blazars respectively. The results are unchanged if we adopt a different value of α (i.e., $\alpha = 3$ or 4).

4. Discussion

The radiation from GRBs and blazars is believed to originate from the relativistic jets with very small viewing angles. Therefore, the beaming effect should be very important for both of these two kinds of sources. The strong correlation between the luminosity and Doppler factor in both GRBs and blazars indeed support this scenario. The most prominent result in this work is that both GRBs and blazars follow the same $L_{\text{syn}} - \mathcal{D}$ correlation (see Figure 2), where L_{syn} is proportional to $\mathcal{D}^{3.1}$ for the whole sample. This relation should be

very useful to investigate the jet physics in GRBs and blazars. One of the possibilities is that GRBs and blazars have, more or less, similar intrinsic luminosities, and their luminosities are enhanced by the beaming effect in the same way due to the possible similar jet physics (e.g., the beaming factor indices α is similar for both of them). We note that the slope of the best-fitted line of the blazar sample is shallower than that of the whole sample, while the best-fitted line of the GRB sample show a steeper slope. The physical reason is unclear, and more observational data are expected for the further test on this issue. The well-known definition of the T_{90} duration is not adopted to calculate the luminosity due to the light curve of GRBs is normally very complex (e.g., Paciesas et al. 1999). In particular, there exist quiescent periods in the light curve of some long GRBs (e.g., Ramirez-Ruiz et al. 2001). Therefore, we choose the burst duration, T_{R45} , in this work to estimate the luminosity of GRBs, even if we are not sure it is the best.

The peak energy, E_{peak} , is a crucial parameter in GRBs, at which most of the emission is radiated. After considering the redshift- and Doppler-corrections (equation 4), we find that the intrinsic values of the peak energy range from ~ 0.1 to ~ 3 keV with a typical value ~ 1 keV for the GRBs in our sample, which is nearly five orders magnitude higher than that of blazars in our sample (see Figure 3). We note that the intrinsic peak energy of some GRBs with $E'_{\text{peak}} \sim 0.1$ keV is just a little bit higher than that of *high-frequency peaked* BL Lacs with peak energy of the synchrotron emission of $E'_{\text{peak}} \sim 0.01$ keV (or $\nu'_{\text{peak}} \sim 10^{15}$ Hz, e.g., Nieppola et al. 2008).

The $E_{\text{peak}}-E_{\text{iso}}$ (or $E_{\text{peak}}-L_{\text{iso}}$) correlation is one of the most thoroughly studied correlations in GRBs. However, its physical origin is still unclear. One possibility is that both peak energy and isotropic energy/luminosity are enhanced by the beaming effect. Eichler & Levinson (2006) proposed that the intrinsic peak energy and intrinsic isotropic energy are similar for different GRBs, and the observed positive correlation is caused by the beaming effect. We test this issue with our GRB sample. The intrinsic synchrotron luminosity is derived with $L'_{\text{syn}} = L_{\text{syn}}/\mathcal{D}^\alpha$, where the beaming factor index α is 3 or 4 for a continuous jet or a moving sphere. Here we simply assume $\alpha = 3.5$ due to the lack of enough knowledge of the jets. After eliminating the beaming effect for both quantities, we find that E'_{peak} is still positively correlated to L'_{syn} for GRBs, which is similar to that of blazars (see Figure 4). Nieppola et al. (2008) also pointed out that the blazar sequence may be the artefact of the Doppler boosting. They found that the negative correlation between the synchrotron peak frequency and the peak luminosities becomes positive after considering the Doppler corrections. The synchrotron peak luminosities equal approximately to the total synchrotron luminosities in our work. The similar trend in the relation of intrinsic peak energy and intrinsic luminosity suggests that both GRBs and blazars are probably governed by the similar jet physics. The physical mechanism for this positive correlation is

still unclear, which may be partly caused by both of these two quantities depending on B' and γ_p (e.g., $E'_{\text{peak}} \propto B' \gamma_p^2$ and $L'_{\text{syn}} \propto B'^2 \gamma_p^2$), where B' is the magnetic field strength in comoving frame and γ_p is the energy of electrons emitting at the peaks of the SED. Therefore, our results indicate that both the beaming effect and the positive correlation between the intrinsic peak energy and intrinsic luminosity may be responsible for the observed tight correlation of $E_{\text{peak}}-L_{\text{iso}}$ (or $E_{\text{peak}}-E_{\text{iso}}$).

The relations of $L_{\text{syn}} - \mathcal{D}$ and $E'_{\text{peak}}(\text{or } \nu'_{\text{peak}})-L'_{\text{syn}}$ in GRBs and blazars suggest that there may exist some physical similarities in their relativistic jets, besides their phenomenally similar viewing angle $\theta \rightarrow 0^\circ$ and relativistic jet speed ($v \rightarrow$ light speed c). Wang & Wei (2011) also found that the GRB afterglows share similar radiation processes with high frequency-peaked BL Lacs, which suggests that the jet emission in GRBs may be analogous to that of blazars. Ghirlanda et al. (2011) proposed that the beaming correction for the intrinsic luminosities of the GRBs may be different from that of blazars, where the beaming factor index α is 2 ($L'_{\text{syn}} = L_{\text{syn}}/\mathcal{D}^\alpha$), not 3 or 4 as used in blazars, due to the emitting region in “fireball” of GRBs have a radial distribution of velocities while the “blob” of blazars have a mono-directional velocity. If this is the case, the correlation between the synchrotron luminosity and Doppler factor (equation 1) suggests that the intrinsic synchrotron luminosity of GRBs should be correlated with the Doppler factor. We find that our conclusion on the positive correlation between the intrinsic luminosities and the intrinsic peak energy of GRBs remains unchanged if we use the beaming factor index $\alpha = 2$, through the intrinsic luminosity will be several orders of magnitude higher than that derived from the beaming factor index $\alpha = 3$ or 4. It is still unclear whether the “fireball” of GRBs is different from the “blob” of blazars or not, since both of them may be caused by similar physical processes (e.g., internal shock scenario, Rees & Meszaros 2002, or internal collision induced magnetic reconnection and turbulence model, Zhang & Yan 2011, or Cannonball model, Dar & de Rujula 2004, etc.).

It should be noted that the assumption of synchrotron emission as the main radiation mechanism for the prompt emission of GRBs still suffers some criticisms (e.g., Zhang 2011). The prompt γ -ray emission can also be explained by other models (e.g., thermal emission from the photosphere, Pe’er & Ryde 2011; or the inverse Compton emission of Cannonball model, Dar & de Rujula 2004, etc.). If this is the case, our results of the E'_{peak} distribution and $E'_{\text{peak}}-L'_{\text{syn}}$ correlation in the comoving frame for GRBs also provide useful clues to constrain these models. More detailed analysis is required to further constrain these models, which will be our future work.

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REFERENCES

- Abdo, A. A., et al. 2010, *ApJ*, 716, 30
- Amati, L., et al. 2002, *A&A*, 390, 81
- Band, D., et al. 1993, *ApJ*, 413, 281
- Böttcher, M. 2007, *Ap&SS*, 309, 95
- Butler, N. R., Bloom, J. S., Poznanski, D. 2010, *ApJ*, 711, 495
- Butler, N. R., Kocevski, D., Bloom, J. S., Curtis, J. L. 2007, *ApJ*, 671, 656
- Dar, A., & de Rujula, A. 2004, *Physics Reports*, 405, 203
- Eichler, D., & Levinson, A. 2006, *ApJ*, 649, 5
- Fenimore, E. E., Epstein, R. I., & Ho, C. 1993, *A&AS*, 97, 59
- Firmani, C., Cabrera, J. I., Avila-Reese, V., Ghisellini, G., Ghirlanda, G., Nava, L., & Bosnjak, Z. 2009, 393, 1209
- Fossati, G., Maraschi, L., Celotti, A., Comastri, A., Ghisellini, G. 1998, *MNRAS*, 299, 433
- Ghirlanda, G., Ghisellini, G., & Lazzati, D. 2004, *ApJ*, 616, 331
- Ghirlanda, G., Nava, L., & Ghisellini, G. 2010, *A&A*, 511, 43
- Ghirlanda, G., Nava, L., Ghisellini, G., Celotti, A., Burlon, D., Covino, S., & Melandri, A. 2011, submitted to *MNRAS*
- Ghisellini, G., Tavecchio, F., Foschini, L., Ghirlanda, G., Maraschi, L., & Celotti, A. 2010, *MNRAS*, 402, 497

- Ghisellini, G., Celotti, A., Fossati, G., Maraschi, L., & Comastri, A. 1998, MNRAS, 301, 451
- Ghisellini, G.; Padovani, P.; Celotti, A.; & Maraschi, L. 1993, ApJ, 407, 65
- Hovatta, T., Valtaoja, E., Tornikoski, M., & Lähteenmäki, A. 2009, A&A, 494, 297
- Lähteenmäki, A., & Valtaoja, E. 1999, ApJ, 521, 493
- Liang, E. W., Dai, Z. G., & Wu, X. F. 2004, ApJ, 606, 29
- Liang, E.-W., Yi, S.-X., Zhang, J., Lü, H.-J., Zhang, B.-B., Zhang, B. 2010, ApJ, 725, 2209
- Liu, T., Liang, E.-W., Gu, W.-M., Zhao, X.-H., Dai, Z.-G., & Lu, J.-F. 2010, A&A, 516, 16
- Lu, R.-J., Hou, S.-J., Liang, E.-W. 2010, ApJ, 720, 1146
- Mészáros, P. 2006, Reports on Progress in Physics, 69, 2259
- Mészáros, P., Rees, M. J., & Papathanassiou, H. 1994, ApJ, 432, 181
- Nieppola, E., Valtaoja, E., Tornikoski, M., Hovatta, T., & Kotiranta, M. 2008, A&A, 488, 867
- Paciesas, W. S., et al. 1999, ApJS, 122, 465
- Pe’er, A., & Ryde, F. 2011, ApJ, 732, 49
- Pe’er, A., Ryde, F., Wijers, R. A. M. J., Mészáros, P., & Rees, M. J. 2007, 664, 1
- Ramirez-Ruiz, E., Merloni, A., & Rees, M. J. 2001, 324, 1147
- Rees, M. J., & Meszaros, P. 1994, ApJ, 430, 93
- Rees, M. J. 1978, MNRAS, 184, 61
- Reichart, D. E., Lamb, D. Q., Fenimore, E. E., Ramirez-Ruiz, E., Cline, T. L., & Hurley, K. 2001, ApJ, 552, 57
- Ryde, F. 2004, ApJ, 614, 827
- Sari, R., & Piran, T. 1999, 520, 641
- Savolainen, T., Homan, D. C., Hovatta, T., Kadler, M., Kovalev, Y. Y., Lister, M. L., Ros, E., & Zensus, J. A. 2010, A&A, 512, 24

- Tavani, M. 1996, *ApJ*, 466, 768
- Yonetoku, D., Murakami, T., Nakamura, T., Yamazaki, R., Inoue, A. K., Ioka, K. 2004, *ApJ*, 609, 935
- Wang, J., & Wei, J. Y. 2011, *ApJ*, 726, 4
- Wu, Z.-Z., Gu, M.-F., & Jiang, D.-R. 2008, *Research in Astronomy and Astrophysics*, 9, 168
- Zhang, B., & Mészáros, P. 2002, *ApJ*, 581, 1236
- Zhang, B., & Yan, H. 2011, *ApJ*, 726, 90
- Zhang, B. 2011, To appear in a special issue of *Comptes Rendus Physique* "GRB studies in the SVOM era", Eds. F. Daigne, G. Dubus, arXiv: 1104.0932
- Zou, Y.-C., Fan, Y.-Z., Piran, T. 2011, *ApJ*, 726, 2

Table 1. The data of GRB and Blazar

Source	z	$\log E_{\text{iso}}$ (10^{52} ergs)	T_{R45} (s)	$\log L_{\text{syn}}$ (ergs s $^{-1}$)	Γ_0	θ	\mathcal{D}	E_{peak} (keV)
GRB								
050730	3.97	9^{+8}_{-3}	21 ± 1	$52.33^{+0.28}_{-0.18}$	289^{+41}_{-28}	$\sim 0^\circ$	578^{+82}_{-56}	196^{+563}_{-87}
050820A	2.615	97^{+31}_{-14}	11 ± 0.8	$53.50^{+0.12}_{-0.07}$	332^{+42}_{-21}	$\sim 0^\circ$	664^{+84}_{-42}	490^{+720}_{-300}
060418	1.49	10^{+7}_{-2}	14.5 ± 0.5	$52.23^{+0.23}_{-0.10}$	379^{+33}_{-10}	$\sim 0^\circ$	758^{+66}_{-20}	217^{+472}_{-87}
060605	3.8	$2.5^{+3.1}_{-0.6}$	5.4 ± 0.5	$52.35^{+0.35}_{-0.12}$	283^{+44}_{-9}	$\sim 0^\circ$	566^{+88}_{-18}	142^{+359}_{-50}
060607A	3.082	9^{+7}_{-2}	15.1 ± 0.8	$52.39^{+0.25}_{-0.11}$	426^{+41}_{-12}	$\sim 0^\circ$	852^{+82}_{-24}	139^{+218}_{-41}
060904B	0.703	$0.72^{+0.43}_{-0.43}$	5.9 ± 0.6	$51.32^{+0.20}_{-0.39}$	155^{+14}_{-14}	$\sim 0^\circ$	310^{+28}_{-28}	83^{+128}_{-25}
061007	1.262	$104.7^{+6.9}_{-6.9}$	16.8 ± 0.2	$53.15^{+0.03}_{-0.03}$	627^{+5}_{-5}	$\sim 0^\circ$	1254^{+10}_{-10}	840^{+1100}_{-330}
070318	0.84	$1.45^{+0.38}_{-0.38}$	10.3 ± 0.5	$51.41^{+0.10}_{-0.13}$	206^{+10}_{-10}	$\sim 0^\circ$	412^{+20}_{-20}	196^{+445}_{-78}
070411	2.954	10^{+8}_{-2}	32 ± 1	$52.09^{+0.26}_{-0.10}$	299^{+30}_{-8}	$\sim 0^\circ$	598^{+60}_{-16}	120^{+556}_{-39}
070419	0.97	$0.24^{+0.23}_{-0.05}$	37 ± 4	$50.11^{+0.29}_{-0.10}$	131^{+16}_{-4}	$\sim 0^\circ$	262^{+32}_{-8}	27^{+16}_{-19}
071010	0.98	$0.13^{+0.24}_{-0.01}$	4.7 ± 0.1	$50.74^{+0.45}_{-0.03}$	145^{+34}_{-4}	$\sim 0^\circ$	290^{+68}_{-8}	37^{+49}_{-35}
071031	2.692	$3.9^{+4.1}_{-0.6}$	34 ± 4	$51.63^{+0.31}_{-0.07}$	191^{+25}_{-4}	$\sim 0^\circ$	382^{+50}_{-8}	12^{+6}_{-11}
080319C	1.95	$22.6^{+3.4}_{-3.4}$	5.0 ± 0.3	$53.12^{+0.06}_{-0.07}$	327^{+7}_{-7}	$\sim 0^\circ$	654^{+14}_{-14}	157^{+303}_{-50}
080330	1.51	$0.41^{+0.94}_{-0.06}$	4.0 ± 0.6	$51.41^{+0.52}_{-0.07}$	150^{+43}_{-3}	$\sim 0^\circ$	300^{+86}_{-6}	20^{+6}_{-19}
080710	0.845	$0.8^{+0.8}_{-0.4}$	23 ± 3	$50.81^{+0.30}_{-0.30}$	90^{+11}_{-6}	$\sim 0^\circ$	180^{+22}_{-12}	300^{+550}_{-200}
080810	3.35	30^{+20}_{-20}	31 ± 2	$52.62^{+0.22}_{-0.48}$	588^{+49}_{-49}	$\sim 0^\circ$	1176^{+98}_{-98}	370^{+620}_{-220}
081203A	2.1	17^{+13}_{-4}	31 ± 1	$52.23^{+0.25}_{-0.12}$	315^{+30}_{-9}	$\sim 0^\circ$	630^{+60}_{-18}	201^{+440}_{-75}
070208 ^a	1.165	$0.28^{+0.22}_{-0.08}$	4.6 ± 0.8	$51.12^{+0.25}_{-0.15}$	115^{+23}_{-20}	$\sim 0^\circ$	230^{+46}_{-40}	66^{+179}_{-33}
080319C ^a	1.95	$22.6^{+3.4}_{-3.4}$	5.0 ± 0.3	$53.12^{+0.06}_{-0.07}$	301^{+39}_{-39}	$\sim 0^\circ$	602^{+78}_{-78}	157^{+303}_{-50}
991203	1.60	436.5^{+60}_{-60}	~ 966	$\sim 0^\circ$	~ 1932	781^{+62}_{-62}
050922C	2.198	$5.06^{+0.55}_{-0.55}$	1.2 ± 0.04	$53.13^{+0.04}_{-0.05}$	~ 401	$\sim 0^\circ$	~ 802	183^{+267}_{-55}
060210	3.91	$41.5^{+5.7}_{-5.7}$	36 ± 2	$52.75^{+0.06}_{-0.06}$	~ 381	$\sim 0^\circ$	~ 762	136^{+347}_{-39}
071010B	0.947	$2.55^{+0.41}_{-0.41}$	4.7 ± 0.1	$52.02^{+0.06}_{-0.08}$	~ 309	$\sim 0^\circ$	~ 618	56^{+8}_{-8}
071112C	0.822	$1.79^{+0.26}_{-0.26}$	~ 244	$\sim 0^\circ$	~ 488	422^{+137}_{-87}
blazar								
0133+476	0.859	...	...	47.92	14.4	2.5°	20.5	$10^{-3.78}$
0234+285	1.207	...	...	47.71	12.7	3.5°	16.0	$10^{-4.58}$
0420+014	0.915	...	...	47.66	11.3	1.9°	19.1	$10^{-3.98}$
0528+134	2.07	...	...	48.06	21.4	1.7°	30.9	$10^{-4.58}$
0716+714	0.31	...	...	47.48	10.2	5.3°	10.8	$10^{-2.78}$
0851+202	0.306	...	...	47.32	9.3	1.9°	16.8	$10^{-3.98}$
1055+018	0.888	...	...	48.03	8.8	4.4°	12.1	$10^{-4.28}$
1156+295	0.729	...	...	47.40	25.1	2.0°	28.2	$10^{-4.28}$
1226+023	0.158	...	...	46.98	13.8	3.3°	16.8	$10^{-3.88}$
1253+055	0.536	...	...	47.54	20.8	2.4°	23.8	$10^{-4.78}$
1308+326	0.997	...	...	47.87	22.0	3.6°	15.3	$10^{-4.28}$
1502+106	1.839	...	...	48.39	15.2	4.7°	11.9	$10^{-3.78}$
1510+089	0.36	...	...	46.53	20.6	3.4°	16.5	$10^{-4.28}$
1749+096	0.322	...	...	46.47	8.0	4.2°	11.9	$10^{-4.28}$
2200+420	0.069	...	...	45.89	5.4	7.5°	7.2	$10^{-3.78}$
2251+158	0.859	...	...	48.46	19.5	1.3°	32.9	$10^{-3.78}$
0814+425	0.245	...	...	45.66	2.7	8.6°	4.6	$10^{-4.18}$
1803+784	1.814	...	...	47.23	9.4	4.5°	12.1	$10^{-3.88}$
2227+088	0.684	...	...	48.13	10.0	3.0°	15.8	$10^{-3.88}$
2230+114	1.037	...	...	47.66	15.4	3.7°	15.5	$10^{-4.18}$
0235+164	0.94	...	...	47.83	12.1	0.4°	24.0	$10^{-3.88}$

^a The Lorentz factors are estimated from their X-ray light curves, while they are estimated from the optical light curves for all other GRBs.

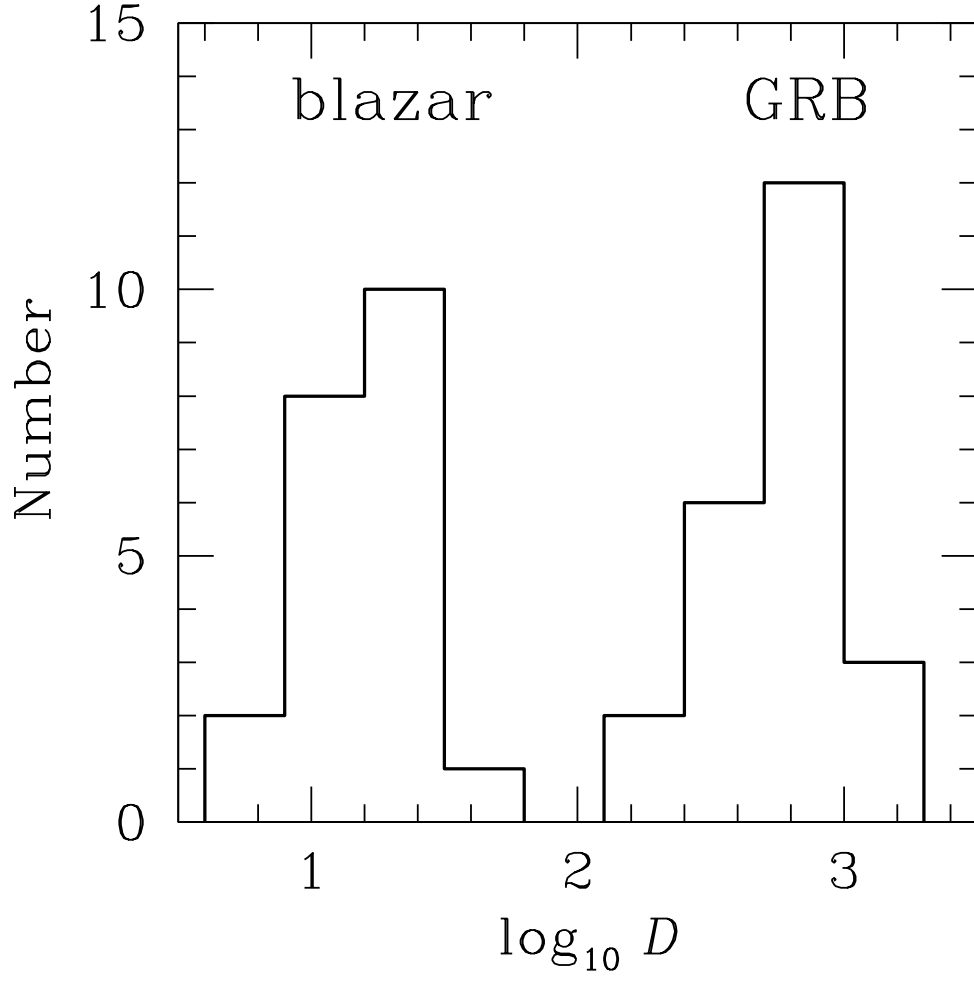


Fig. 1.— Distribution of the Doppler factors, \mathcal{D} , for blazars and GRBs.

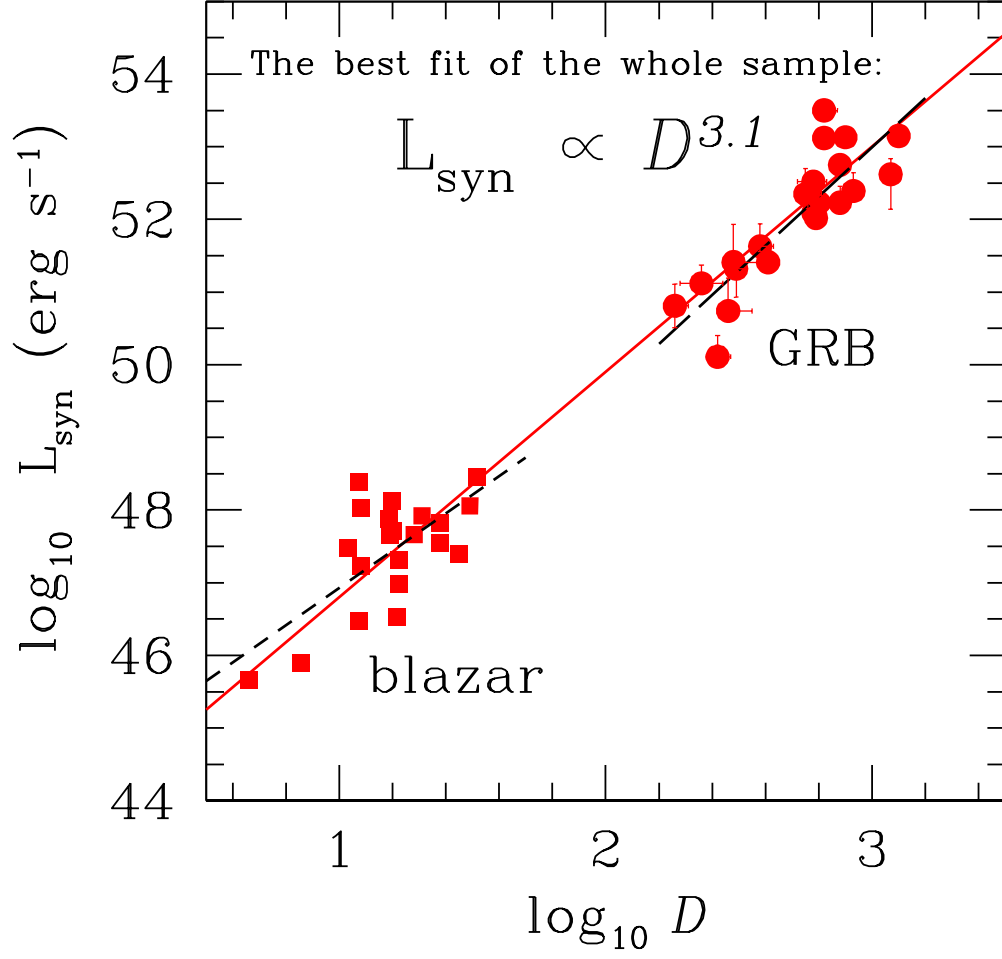


Fig. 2.— The synchrotron luminosity, L_{syn} , vs Doppler factor, \mathcal{D} , correlation for GRBs and blazars. The long-dashed line, short-dashed line and solid line represent the best linear fits of GRBs, blazars and both of them respectively.

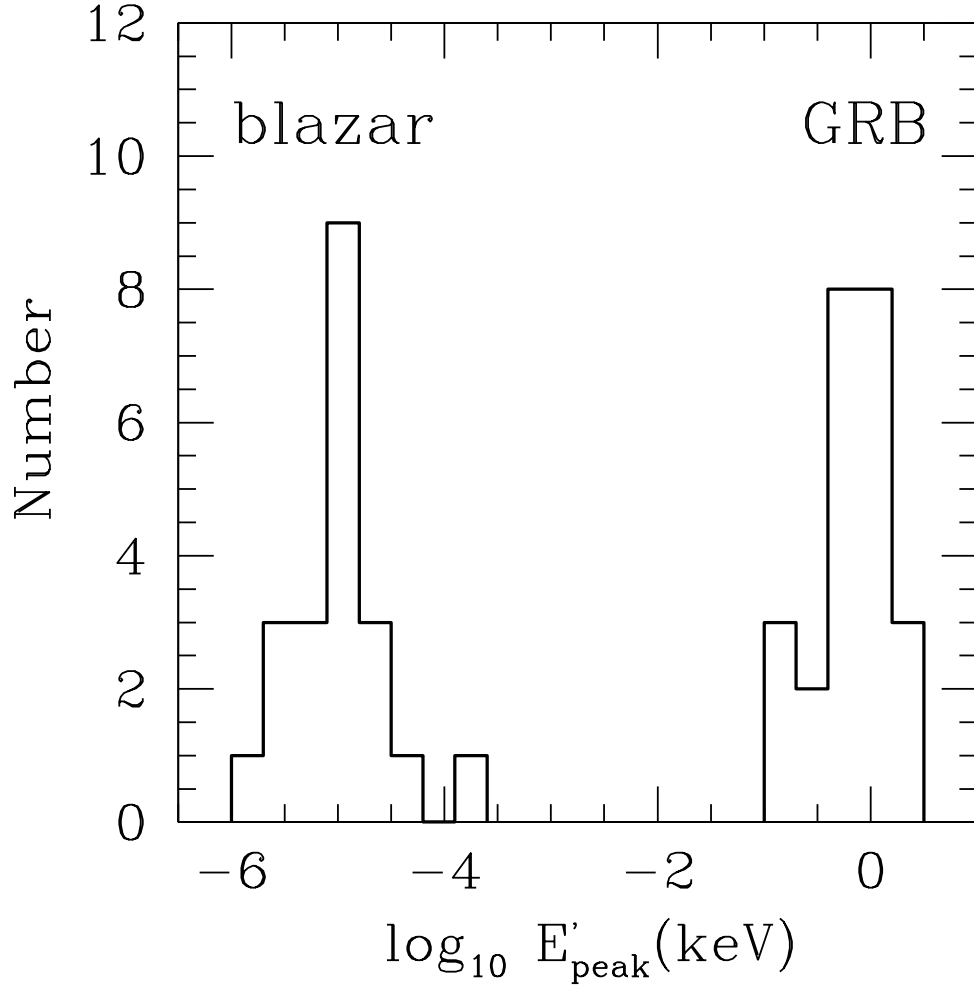


Fig. 3.— Distribution of the intrinsic peak energy, E'_{peak} , for blazars and GRBs after redshift- and Doppler-correction.

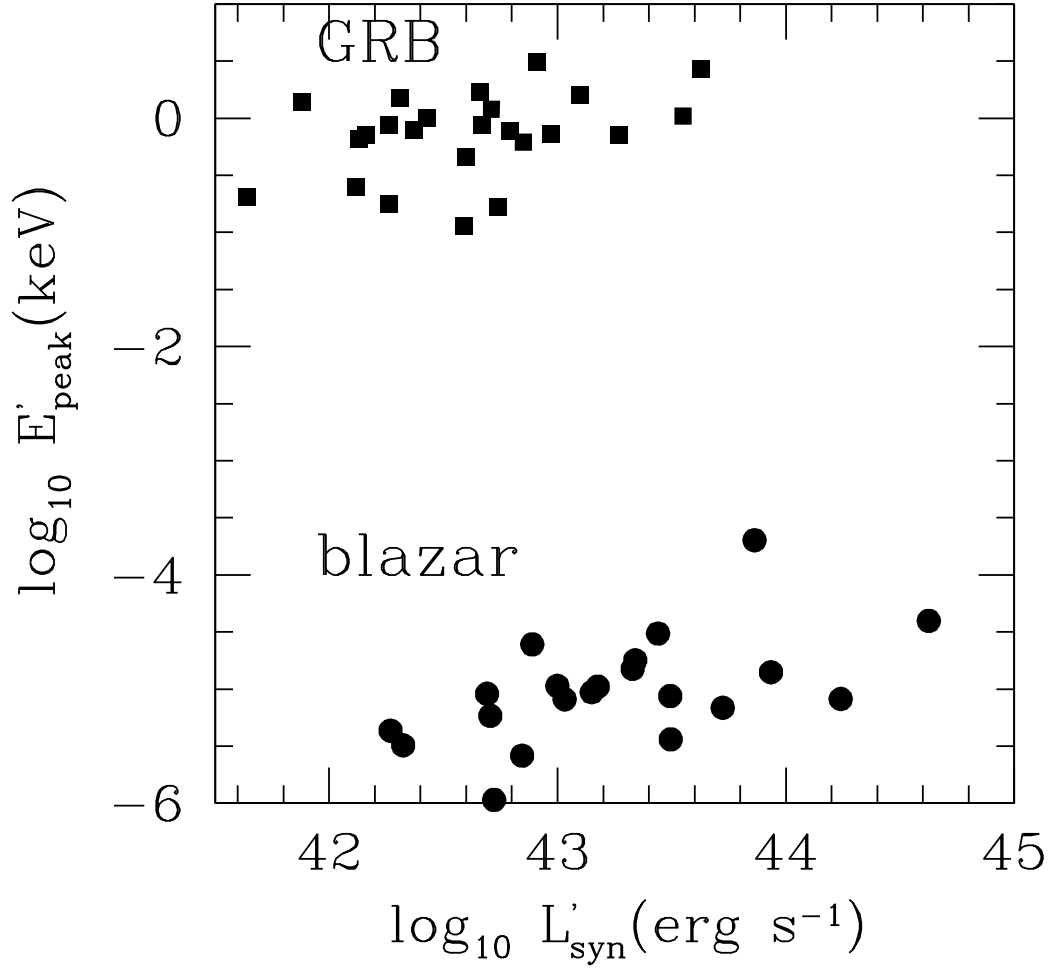


Fig. 4.— Correlation between the intrinsic peak energy, E'_{peak} , and the intrinsic synchrotron luminosity L'_{syn} after correcting the beaming effect with $L'_{\text{syn}} = L_{\text{syn}}/\mathcal{D}^{3.5}$.